Pulmonary Tumor Detection Using Respiratory Lung Sound

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Abstract

The objective of this study was to perform preliminary study to investigate the fact that respiratory lung sound contains useful information for the detection of pulmonary lung tumor. This study covers 3 lung tumor free subjects and 3 patients with confirmed lung cancer. The power spectrum density (PSD) was used to discriminate between the sound of lung tumor free subjects and that of confirmed lung tumor patients.

Our finding is that the PSD of lung sound of lung cancer patients shows a much higher magnitude than that of lung cancer free subjects. In addition, there was a higher number of harmonics with significant magnitude for lung tumor patients compared to that of lung tumor free subjects.

Preliminary results indicate that the PSD of lung sound signals at different lung filed locations was effective in detecting the presence of pulmonary tumor. This observation might be important in using the respiratory lung sound as an inexpensive and noninvasive mean to design computer based pulmonary lung tumor detection systems.

I. Introduction

Malignancies affecting the lungs are the leading cause of cancer deaths in men and women.

Furthermore, pulmonary malignancies are responsible for the most years of life lost of all oncology diseases [1]. Despite lot of advancement in treatment protocols for pulmonary malignancies, overall survival data still remain suboptimal. Previous studies have indicated that respiratory sound signals may contain information useful in the detection of lung diseases [2-5]. In recent years, diagnostic using auscultation has significantly improved because of recent advances in data acquisition, modeling, and digital signal processing [5-8]. Respiratory acoustic measurements have also shown promise in the investigation of the upper airway pathology, e.g. in patients with obstructive sleep apnea or tracheal narrowing. The respiratory tract consists of vocal tract, which has been studied extensively, and the sub glottal airways, are now the topic of more detailed acoustic investigations. It is the combined effect of these two components that gives rise to the highly unique properties of the overall tract. The branching airways in the thorax have been modeled by a number of investigators to assess the structural determinants of sound reflection and transmission measurement [9-12]. Although these and other concepts have proven useful in many clinical circumstances, most acoustic investigations [13-16] with high fidelity measurements indicate that considerably more information of clinical utility can be gathered from respiratory sound .

New diagnostic and treatment strategies are needed if an impact is to be made on survival of patients diagnosed with lung tumor. Patients with lung cancer often have solitary pulmonary nodules on chest radiographs performed as preoperative evaluation or part of routine physical examinations. Chest radiography, computed tomography [CT] and magnetic resonance imaging [MRI] are frequently obtained in patients with suspected lung tumor. These modalities provide anatomic and morphologic information but they are not capable of accurately characterizing lung, pleural or lymph node abnormalities as benign or malignant despite their high cost. The accurate diagnosis has required tissue obtained by sputum cytology, bronchoscope, percutaneous needle biopsy, thoracoscopic or open lung biopsy.

Considering the above, it is clear that lung sound signals have useful information about the presence of lung diseases. However, the use of lung sound for pulmonary tumor detection has not been investigated. The use of respiratory lung sound for the detection of lung tumor is the motivation for this work. The long term objective is the design of computer based detection of lung tumor using the respiratory lung sound as a noninvasive and inexpensive source of information.

The method used in this study consists of collecting lung sound data for patients with confirmed lung tumor as well as subjects that have no known lung tumor. The data is then processed by removing measurement noises and computing the power spectrum density of the lung sound at different locations of the lung for each subject and each patient. Finally, a comparison of the PSD of lung tumor free subjects to that of the lung tumor patients took place.

II. **Lung Sound Data Collection**

The Lung Cancer of The Cookeville Regional Medical Center (CRMC) provided respiratory lung sound data for lung tumor free subjects as well as patients with confirmed lung cancer tumors. Before the data collection took place, each patient and subject was informed of the study and permission to collect the lung sound data was sought from the patient and subject. To collect respiratory lung sounds, a standard WelchAllyn (Model 5079-400) electronic stethoscope, [17], was used. The stethoscope is a regular stethoscope with an audio output that can be digitized and stored in a laptop using a standard data acquisition card DAQCard-AI16XE-50 [18]. To ensure that most of the lung area is covered, measurements of the lung sound were collected at 15 lung fields. These measurements cover the anterior as well as the posterior area of the lung. The 15 locations are given in Table 1. In this study, the sampling rate used is 2000samples/second. The duration of each experiment is 15 sec. This is to allow the collection of a large amount of data in each experiment.

Detailed information about the subjects and patients used in the study is provided in Table 2, where “F” and “M” indicates female and male, respectively. In each case, lung sound measurements took place at 15 lung filed locations as indicated in Table 1.

Table 1. Lung fields used to measure lung sound

Lung Field	**Anterior Area**	**Posterior Area**
1	Trachea	
2	Upper Right Field	
3	Upper Left Field	
4	Middle Right Field	
5	Middle Left Filed	
6	Lower Right Filed	
7	Lower Left Filed	
8		Upper Left Field
9		Upper Right Field
10		Middle Right Filed
11		Middle Left Filed
12		Lower Left Filed
13		Lower Right Filed
14		Right Costophrenic Angle
15		Left Costophrenic Angle

III. Preprocessing and Feature Extraction

Identical processing was applied to all the signals of all the subjects. A low pass first order Butter Worth filter with corner frequency equal 0.1 is used to remove measurement noise. To help the discrimination of subjects with lungs free of tumor from lung tumor patients, the filtered data has to be processed to extract simple features that can be used for classification.

Table 2. Information about the group of females used in the study

Subject	**Age**	**Sex**	**Lung Condition**
S1	73	F	Non Smoker & Lung Cancer Free
S2	56	F	Smoker & Lung Cancer Free
S3	74	M	Non Smoker & Lung Cancer Free
P1	53	M	Anterior Mediastinal Tumor
P2	74	F	Left Upper Lung Cancer
P3	75	F	Female with Right Upper Lobe Cancer

In this study, the power spectrum density (PSD) of the lung sound was used. Note that the use of the PSD is only one of a variety of information that can be used for signal interpretation and characterization. The power spectrum density of the sound informs us about the presence of meaningful sounds at specific frequencies. Such sounds can indicate the presence of obstructions in the lung due to the possible presence of a tumor.

IV. Results

For the lung tumor free subjects, the PSD was computed at the different 15 lung field for each subject; a total of 45 lung field sounds were analyzed. See Figures 1~2 for samples of lung sound PSD versus frequency at different lung fields. The largest peak of the 45 PSD computed was less than 3, see Table 3. Similar analysis was done for each lung sound of the lung cancer patients, see Table 4. It was found that for each lung cancer tumor patient, the peak of the PSD in at least one lung filed location was much higher than the largest peak of the PSD, which is 2.9 in this study, of all lung tumor free subjects. In addition, it was observed that the peak value of the PSD of a patient is much higher a given location at all the other locations. For example, the PSD of Patient P3 at the lower right lung field (field 6) has a peak 36, while its peak at the upper left lung filed (field 3) is only 4.5. This may be helpful in isolating the tumor location.

Table 3. Maximum Peak Value of Lung Sound for lung Cancer Free Subjects

Subject	S1	S2	S3
Max(PSD)	2.859	1.665	1.4037

Table 4. Maximum Peak Value of Lung Sound for lung Cancer Patients

Patient	P1	P2	P3
Max(PSD)	12.366	17.361	36.41

V. Discussions

The results of the study, as partially depicted by Tables 3~4, clearly shows that there is a huge difference between the peak value of the PSD of all lung tumor free subjects and that of any confirmed lung cancer tumor patient. The higher amplitudes and increase in frequency harmonics for lung cancer patients may be attributed to pathological effect produced by pulmonary tumor. In fact, pulmonary tumor can lead to tissue injury especially in superficial epithelium of lung tissue which produces a variety of pro-inflammatory epithelial derived cytokines that drive the remodeling response in sub-epithelial compartment of lung [19]. This remodeling process produces changes in airway dimensions (both small and large airways) in relation to the lung function of patients of lung tumor [20]. Such changes in airway dimensions can affect the propagations of the air through lungs and create the higher amplitudes and harmonics in PSD for patients with pulmonary tumors.

This study appears to confirm the hypothesis that respiratory lung sound can be useful, as noninvasive mean, in the detection of the presence of pulmonary tumor.

This study suggested that a computer based lung tumor detection system can be designed to perform pulmonary lung tumor detection using the PSD of respiratory lung sound. This can be accomplished using a simple thresholding technique.

One of the results of this study also indicated that for each patient, with a lung cancer tumor, his/her lung sound has a PSD peak at a particular lung field that is significantly higher than the peaks at the remaining lung fields of the patient. This seems to suggest that, not only the respiratory lung sound can be useful in detecting the presence of a lung tumor; it can also help in determining the approximate location where the tumor is present.

To conclude, in confirmed lung cancer patients, there are indications of increased amplitudes and increase in frequency harmonics in PSD of lung sound signals at different field locations. This observation might be important in using the respiratory lung sound as an inexpensive and noninvasive mean to design computer based pulmonary lung tumor detection systems.

Further work is needed to cover a large number of subjects and patients. Additionally, data will need to be collected to learn the difference in lung sound patterns between a patient with lung tumor and that of other pulmonary symptoms diseases such as crackles and wheezing.

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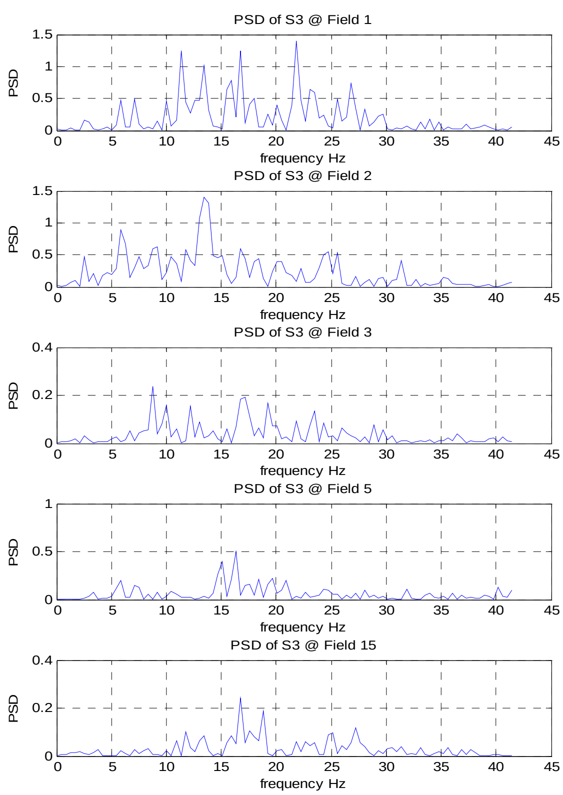

Figure 1. PSD at different lung fields for Subject S3

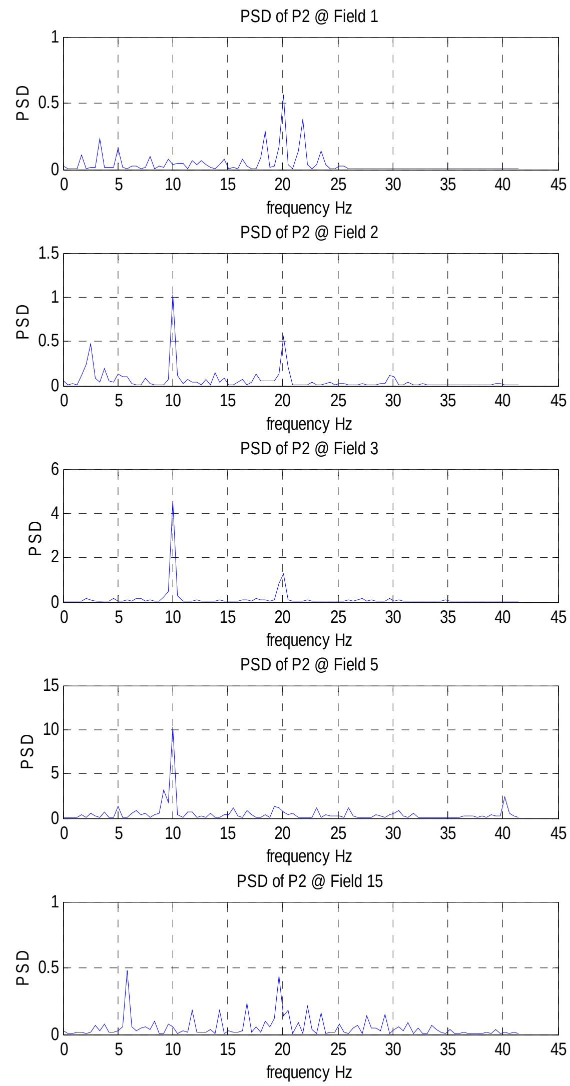

Figure 2. PSD at different lung fields for Patient P2